

Lunar Reconnaissance Orbiter Project

Lunar Reconnaissance Orbiter Solar Array Statement of Work

December 16, 2005

LRO GSFC CMO

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RELEASED



National Aeronautics and
Space Administration

**Goddard Space Flight Center
Greenbelt, Maryland**

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LRO CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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LUNAR RECONNAISSANCE ORBITER PROJECT**DOCUMENT CHANGE RECORD**

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
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1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The National Aeronautics and Space Administration (NASA) has the stated mission to design, develop, integrate, launch, and operate the Lunar Reconnaissance Orbiter (LRO).

The LRO is the first mission of the Robotic Lunar Exploration Program (RLEP). The primary objective of the mission is to conduct measurements that will facilitate the safe return of humans to the moon. LRO is scheduled to launch in 2008 into a lunar polar orbit with a mission life of fourteen months.

1.2 GENERAL REQUIREMENTS

The Contractor shall provide the facilities, personnel, services, tools, equipment, and materials to deliver the items in the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

1.3 APPLICABLE DOCUMENTS AND DOCUMENT PRECEDENCE

In the event of a conflict between this Statement of Work (SOW) and the Lunar Reconnaissance Orbiter Solar Specification (431-SPEC-000037), this SOW shall take precedence. In the event of conflict between this SOW or the Lunar Reconnaissance Orbiter Solar Specification (431-SPEC-000037) and the documents listed below, this SOW or the Lunar Reconnaissance Orbiter Solar Specification (431-SPEC-000037) shall take precedence.

All referenced documentation identified in the SOW shall apply in the situations where they are specifically referenced.

1.3.1 Applicable Documents

DOCUMENT NUMBER	TITLE	Revision/Date
431-LIST-000410	Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule	Rev - 1/17/2006
431-SPEC-000037	Lunar Reconnaissance Orbiter Solar Array Specification	Rev - 1/17/2006

1.3.2 Reference Documents

DOCUMENT NUMBER	TITLE	Revision/Date
541-PG-8072.1.2	GSFC Fastener Integrity Requirements	03/05/01
ANSI/ASQ9001-2000	Model for Quality Assurance Design, Development, Production, Installation, and Servicing	Aug 1991
ASTM E-595	Standard test method for total mass loss and collected volatile condensable materials from outgassing in a vacuum environment	10/1/03

DOCUMENT NUMBER	TITLE	Revision/Date
NASA-STD-8739.7	Electrostatic Discharge Control	12/15/97
NASA-STD-8739.3	Requirements for Soldered Electrical Connections	12/15/97
NASA-STD-8739.4	Requirements for Crimping Inter-connecting Cables, Harnesses, and Wiring	02/09/98
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology	08/31/99
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies	08/06/99
S312-P-003	Procurement Specification for Rigid Printed Boards for Space Flight Applications and Other High Reliability Uses	07/16/97 Revision B
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating	05/01/03
IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies	09/30/91
IPC-2223	Sectional Design Standard for Flexible Printed Boards	11/01/98
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards	02/01/98
IPC-2221	Generic Standard on Printed Board Design	05/01/03 Revision A
IPC-A-600	Acceptability of Printed Boards	11/01/99 Revision F
IPC-6011	Generic Performance Specification for Printed Boards	07/01/96
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards	07/01/00 Revision A
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards	11/01/98
JPL Publication 96-9	GaAs Solar Cell Radiation Handbook	1996
MIL-HBK-217	Reliability Modeling Prediction	
S-311-M-70	Destructive Physical Analysis. Equivalent	1/7/91 Revision A
NASA-STD-6001	Flammability, odor, off-gassing and compatibility requirements & test procedures for materials in environments that support combustion	2/9/98
MIL-STD-1629	Procedures for Performing an FMEA	Revision A
MIL-HBK-217	Reliability Modeling and Prediction	Revision F

DOCUMENT NUMBER	TITLE	Revision/Date
MSFC-STD-3029	Multiprogram/project common-use document guidelines for the selection of metallic materials for stress corrosion cracking resistance in sodium chloride environments	5/22/00

2.0 MANAGEMENT, REPORTING, DOCUMENTATION, AND REVIEWS

2.1 MANAGEMENT AND REPORTING

The Contractor shall designate and identify by name a single individual, who shall have full responsibility and authority to manage and administer the work specified by the contract associated with this SOW.

The Contractor shall designate and identify by name a single individual, who shall serve as a point of contact with the GSFC Contracting Officer Technical Representative (COTR) for technical aspects of the contract enforcing this document.

The Contractor shall provide for managing resources; controlling schedules; managing engineering, manufacturing and procurement activities; configuration management (CM); quality assurance (QA); documentation control, and distribution.

2.2 AVAILABILITY OF DOCUMENTS

In addition to documentation specifically called for in the Contract and the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410), the Contractor shall make available, upon request by the Goddard Space Flight Center (GSFC) COTR, a copy of any document or data generated during this contract performance for review by the GSFC at the Contractor's facility, or, if the document or data is not competition sensitive, via the internet or via e-mail. This includes, but is not limited to, technical reports and memorandums, drawings, schematics, studies, analyses, parts and materials data, test data, alerts, etc.

2.3 AVAILABILITY OF DOCUMENTS

2.3.1 Design Conformance Review

The Contractor shall organize and present a Design Conformance Review (DCR) to a GSFC Review Team at the Contractor's facility. This review shall demonstrate overall conformance to this SOW and to the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). This review shall cover programmatic, technical, test and verification, and QA topics. This review shall also provide an opportunity to review drawings and analyses required for approval before the start of fabrication. The Contractor shall supply the documentation listed in the following sub sections, associated with the DCR, in accordance with the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

2.3.1.1 Design Conformance Review Presentation Package

The Contractor shall provide a DCR Presentation Package. This shall address program management, design, analysis, manufacturing, test, and QA activities outlined in this SOW and in the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037), in sufficient detail to ensure that the proposed design conforms to all requirements and is ready for fabrication to begin. In general, the design package shall cover the following:

- Agenda
- Program Management
- Quality Assurance
- Electrical, Mechanical, and Environmental specifications
- Parts, including stress analysis and radiation hardness assessment
- Detailed architectural block diagrams for the different deliverable units
- Manufacturing flow with inspection points
- Facilities
- Verification test plan (Including Performance Test Description)
- Materials and Processes
- Electrical Worst-Case analyses
- Failure Modes Effects Analyses
- Flight Heritage

GSFC shall not close the DCR until all open action items have been closed and approved to its satisfaction.

2.3.1.2 Design Conformance Review Flight Panel Output Predictions

The Contractor shall include a prediction of the output of the flight panels under test condition, at beginning of life (BOL), and at end of life (EOL). The Contractor shall specify the radiation model it used in computing array degradation as a function of radiation.

The Contractor shall supply the reliability prediction required by Section 4.3.4.

2.3.1.3 Typical Cell I-V Curves

The Contractor shall supply an I-V curve for a typical solar cell in parallel with a typical bypass diode. The I-V curve shall represent measured data at 28C and measured data at the highest and lowest predicted operating temperatures of the flight LRO solar panels. Each I-V curve shall consist of a minimum of 100 measured current voltage points. The curve shall be taken from a minimum of three times the cell's short circuit current at "negative" voltage to a current greater than 25% of the absolute value of the cell's short circuit current at a voltage greater than Voc. The contractor shall supply these measured curves for an un-shadowed cell and for a cell with 50% shadowing. The I-V curves shall be provided in tabular form at a precision of three significant digits for current and voltage.

2.3.1.4 Cell Degradation as a Function of 1-MeV Electrons

The Contractor shall supply maximum power (Pmax), Open-Circuit Voltage (Voc), voltage at maximum power (Vmp), and Short-Circuit Current (Isc) of a typical cell as a function of 1 Mega-electron Volts (MeV) electrons at a minimum of five fluences from 0 to 1E15 Equivalent 1 MeV electrons.

For a minimum of five fluences from 0 to 1E15 Equivalent 1 MeV electrons, the Contractor shall supply an I-V curve for a typical solar cell in parallel with a typical bypass diode. The I-V curves shall represent measured data at 28C. Each I-V curve shall consist of a minimum of 100 measured current voltage points. The curve shall be taken from a minimum of three times the cell's short circuit current at "negative" voltage to a current greater than 25% of the absolute value of the cell's short circuit current at a voltage greater than Voc. The I-V curves shall be provided in tabular form at a precision of three significant digits for current and voltage.

2.3.1.5 Solar Cell Radiation Damage Coefficients

The Contractor shall supply the proton and electron damage coefficients of the solar cells in the format, at the shielding thicknesses, and at the energies of Tables 5-1, 5-2 and 5-3 of Jet Propulsion Laboratory (JPL) Publication 96-9.

2.3.1.6 Design Conformance Review Mass Estimate

The Contractor shall also include a mass estimate for the solar panel by component.

2.3.1.7 Design Conformance Review Drawing Package

The Contractor shall supply a drawing package for the flight panels and the qualification panel consisting of: front and rear side assembly drawings, drawings of all Contractor-installed hardware, and wiring diagrams. The package shall specify the location of wire feed thru holes for the cell circuits and their diameter for both the qualification panels, test panels, and the flight panels. The package shall include a paint stay-out drawing or template specifying areas such as spot bond and terminal board locations on the back of the panels that are not to be painted.

2.3.1.8 Verification Matrix

The Contractor shall supply a verification matrix that shall list each requirement and indicate by what methods the Contractor shall verify the requirement. The verification shall include the methods the Contractor shall use to verify: the cell contact strength, the solder ability or weld ability of the cell contacts, the contacts' ability to withstand humidity, the cell antireflective coating performance, the cell absorptance, the cell mechanical performance, the cover glass material and thickness, the cover glass coating performance, the cover glass orientation, the cover glass bonding, the cover glass mechanical performance, the interconnect material, the interconnect soldering or welding, the interconnect mechanical performance, the wiring type, the wiring soldering or welding, the wiring and harness electrical characteristics, and array performance before and after exposure to the space environment. The Contractor shall include pass/fail criteria for each item to be verified. Some of the verifications are required in some detail by this SOW and by Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). The Contractor shall determine the other verifications at Pre-Environmental Review (PER) and shall notify the COTR of any subsequent changes to previous verification plans. The Contractor shall supply verification plans and procedures for the qualification panel.

2.3.1.9 Preliminary Flight Panel Test Plan

The Contractor shall supply a preliminary test plan for the flight panels that shall consist of the sequence of the tests and inspections, a brief description of each test and inspection apparatus, and

list the detailed procedures for performing each test and inspection including pass/fail criteria for each test and inspection. Detailed verification test procedures for the flight panels may be deferred until the PER. The plan shall state the purpose of each test, state acceptance criteria, describe in detail the test method and instrumentation, and give the sequence of the tests. The plan shall include a test matrix summarizing all tests that will be performed.

2.3.1.10 Qualification Panel and Test Panel Assembly Test Plan

The Contractor shall supply a Qualification Panel and Test Panel Assembly Test Plan for the verification tests required by the specification. Tests must demonstrate acceptable performance over the specified range of performance requirements, measure performance parameters and reveal inadequacies in manufacturing and assembly such as workmanship or material problems. The plan shall state the purpose of each test, state acceptance criteria, describe in detail the test method and instrumentation, and give the sequence of the tests. The plan shall include a test matrix summarizing all tests that will be performed.

2.3.1.11 Qualification Panel and Test Panel Assembly Test Procedure

The Contractor shall supply Qualification Panel and Test Panel Assembly Test Procedures, step-by-step instructions for performing tests outlined in the Test Plan. The procedures shall define the environmental conditions for the tests, required equipment and facilities, test constraints, use of diagnostic or performance test software, operating conditions, tolerance on all input stimuli, data to be recorded and pass/fail limits. Test procedures shall also include Safe-to-Mate procedures to verify that ground support equipment (GSE) can safely be mated to interfaces and that interfaces are safe to accept mating with the GSE. Test procedures shall be Contractor controlled documents and shall indicate changes made after the initial release.

2.3.1.12 Program Schedule

The Contractor shall supply a schedule that shall include milestone charts depicting critical paths and indicating critical dates in the program. The Contractor shall define the start, implementation, and completion dates for the detailed activities associated with the design, analysis, manufacturing, and testing of all components, subassemblies, and panels. The Contractor shall identify the vendor lead times for procured parts and materials.

2.3.1.13 Design Conformance Review Report

A DCR Report shall be prepared following the review. The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements.

2.3.2 Manufacturing Readiness Review

The Contractor shall organize and conduct a Manufacturing Readiness Review (MRR) at the Contractor's facility after testing of the qualification panel and the Test Panel Assembly are complete and before fabrication of the flight panels begins. This review shall demonstrate overall conformance of the requirements specified for the contract implementing this SOW and the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). This review shall cover

results of the qualification panel and Test Panel Assembly tests. This review shall also cover programmatic, technical, test and verification, and QA topics. This review shall also provide an opportunity to review test plans and procedures and all analyses required to approve the testing of the flight hardware.

The Contractor shall supply the documentation listed in the following subsections, associated with the MRR, in accordance with the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

2.3.2.1 Manufacturing Readiness Review Presentation Package

The Contractor shall provide a MRR Presentation Package. The package shall summarize the material which the Contractor will cover in more detail in the documentation associated with the MRR review. This required documentation is defined in this section. The presentation package shall contain an updated schedule.

2.3.2.2 Manufacturing Readiness Review Flight Panel Output Predictions

The Contractor shall update predictions of the output of the flight panels under test condition, at BOL, and at EOL.

2.3.2.3 Manufacturing Readiness Review Mass Estimate

The Contractor shall update the DCR mass estimate for the array by component.

2.3.2.4 Qualification Panel Report

The Contractor shall report on qualification panel test results. The report shall include a summary of the panel's performance through its environmental tests. The report shall also compare the DCR predictions of the panel's output and mass to its measured output and mass.

2.3.2.5 Flight Panel Test Plan

The Contractor shall write a Test Plan for the verification tests required by this document and by the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). Tests must demonstrate acceptable performance over the specified range of performance requirements, measure performance parameters and reveal inadequacies in manufacturing and assembly such as workmanship or material problems.

The plan shall state the purpose of each test, state acceptance criteria, describe in detail the test method and instrumentation, and give the sequence of the tests. The plan shall include a test matrix summarizing all tests that will be performed.

This contractor shall formally control this document and shall indicate all changes made after the initial approval by the GSFC. After test plan approval, the National Aeronautics and Space Administration (NASA) COTR must approve all changes in writing.

2.3.2.6 Flight Panel Test Procedures

The Contractor shall write and deliver Test Procedures. The verification procedures shall be step-by-step instructions for performing tests outlined in the Test Plan. The procedures shall define the

environmental conditions for the tests, required equipment and facilities, test constraints, use of diagnostic or performance test software, operating conditions, tolerance on all input stimuli, data to be recorded and pass/fail limits. Test procedures shall also include Safe-to-Mate procedures to verify that GSE can safely be mated to interfaces and that interfaces are safe to accept mating with the GSE.

Test procedures shall be Contractor controlled documents and shall indicate all changes made after the initial release for review to NASA.

2.3.2.7 Manufacturing Readiness Review Report

The Contractor shall prepare a Manufacturing Readiness Review (MRR) Report. The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements.

2.3.3 Pre-Ship Review

The Contractor shall hold a Pre-Ship Review (PSR) at the Contractor's plant at the completion of verification tests and prior to shipment of the hardware to GSFC. In general the review shall include:

- Agenda
- As-Built versus As-Designed Parts List, (includes serialization/revisions)
- Final Drawing Package (including rework instructions, if any)
- Critical Parameters Trend Data
- Problem/anomaly reporting (complete copies of report)
- Deviations/Waivers/open items/nonconformances and their dispositions
- Class I Material Review Boards (MRBs) (complete copies of reports)
- List of Materials and Processes used
- Log of total operating time
- List and status of all identified Life-Limited Items
- Verification matrix, test data and reports
- Flight connector mate/demate log (Flight Unit only)
- Photograph Documentation
- Certificate of Conformance

The PSR shall also cover the topics, which the Contractor will cover in more detail by the documentation associated with the PSR. This documentation is listed in this section.

2.3.3.1 Pre-Ship Review Presentation Package

The Contractor shall provide a PSR Presentation Package. The package shall summarize the material, which the Contractor will cover in more detail in the documentation associated with the PSR review. This required documentation is defined in this section.

2.3.3.2 Final Flight Panel Output Estimate

The Contractor shall update predictions of the output of the flight panels under test condition, and at BOL, and at EOL based on the measured value under test conditions.

2.3.3.3 Report on final Mass Measurement

The Contractor shall update the mass estimate for the array by component to reflect measured values.

2.3.3.4 Final Drawing Package

The Contractor shall supply a drawing package for the flight panels consisting of: front and rear side assembly drawings, drawings of all Contractor-installed hardware, and wiring diagrams.

2.3.3.5 Final Verification Matrix

The Contractor shall supply the final verification matrix that shall list each requirement and indicate by what method the requirement has been verified.

2.3.3.6 Acceptance Data Package

The Contractor shall prepare and deliver an acceptance data package to the GSFC with the flight panels in accordance with the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410). For each panel, this report shall contain the as-built configuration list, a list of parts and materials used in the panel, a list of processes used to manufacture the panel, a test log book for each test which documents the total operating time and cycles for each test, a list of open items and the reason the items are open, results of the verifications required by this specification including dates of completion and what test equipment was used, Temperature Controlled Quartz Crystal Microbalances (TQCM) data, a summary of all repairs for that flight panel, a series of 8" X 10" digital color photographs of each side (back and front) of that flight panel, a copy of all MRB actions generated against the panel, and a copy of all problem/failure reports generated against the panel. The Contractor shall document the issue numbers of the drawings and specifications to which particular hardware has been fabricated, inspected, and tested as the as-built configuration. The Contractor shall provide evidence of compliance with the as-built documentation as a basis for acceptance of the hardware.

2.3.3.7 Pre-Ship Review Report

The Contractor shall prepare a PSR Report. The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements. If any of the information presented in the earlier reviews has changed, the Contractor shall present this in the PSR report to GSFC in accordance with the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410). The PSR report, with the

other documentation required in Section 2 of this document, shall present a level of detail to permit a review team to compare the flight panels' design, assembly, acceptance test, and performance against the requirements of this document and the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037).

2.3.4 Technical Interchange Meetings

The Contractor shall plan for informal, face-to-face technical interchange meetings (TIMs) to be held at the Contractor facilities. These TIMs shall support review and coordination of technical issues including, but not limited to, parts, test plans, test procedures, software changes, design modifications, and design analyses. Either the Contractor or GSFC may request a TIM. The requester shall provide notice seven (7) calendar days in advance of the meeting.

2.4 WEEKLY TELECON

The Contractor shall prepare and present to the GSFC a status report by weekly telecon. This shall include, but shall not be limited to a review of the previous week's: accomplishments and progress against the original schedule; procurements; key personnel changes; completed designs, drawings, and documents; material and process changes; test and inspection results; performance assurance issues; requirements verification changes; hardware shipments; action or open items; problems; cost and expenditures; and the next week's planned activities.

2.5 MONTHLY STATUS REPORTS

The Contractor shall prepare and submit to the GSFC a written Monthly Status Report (MSR) to e-mail addresses supplied at contract award in a portable document format (PDF) file. The report shall include the same information reported in the weekly telecons but for the previous month rather than the previous week. In addition the report shall include the next month's planned activities, and updates to the schedule or a statement that the Contractor is on the last schedule submitted.

3.0 HARDWARE MANUFACTURE

3.1 FLIGHT, TEST, AND QUALIFICATION SOLAR PANELS

The Contractor shall supply flight Solar Array Panels, Test Panels, and Qualification Panels to the requirements of the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). The GSFC will bond two of the test panels to a structural frame and wire them together and to connectors. This assembly is called a Test Panel Assembly. The GSFC will then ship the Test Panel Assembly to the Contractor to be tested to the requirements of the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037).

3.2 ISC AND VOC SENSOR PANEL

The Contractor shall supply a Isc and Voc Sensor Panel to the requirements of the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037).

3.3 SUPPORTING HARDWARE

The Contractor shall provide the following supporting hardware:

Electrostatic Discharge (ESD) flight protective caps, as applicable.

3.4 GROUND SUPPORT EQUIPMENT

3.4.1 Standard Cells

The Contractor shall supply a primary or secondary standard cell of the same type used in the manufacture of the flight panels. The contractor shall supply additional standard cells, a “top,” “middle,” and “bottom” having approximately the same spectral response as the flight cell junctions so that the spectral output of the GSFC Large Area Pulsed Solar Simulator (LAPSS) can be adjusted to properly stimulate the flight cell junctions.

3.5 REPAIR PARTS

The Contractor shall supply parts sufficient to repair damaged solar cells on the completed panels according to the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

The Contractor shall supply each type wire it has used in fabricating the panels according to the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

The Contractor shall supply repair parts for each type of interconnect it has used in fabricating the panels according to the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

The Contractor shall supply blocking diodes of the type it has used in fabricating the panels according to the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

The Contractor shall supply terminal boards of each type it has used in fabricating the panels according to the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

With the exception of adhesives, other parts the contractor deems necessary to repair the panels.

The following sentence is information only and is not a requirement. The GSFC may issue a time and materials contract to the Contractor to repair the solar panels using the above deliverables sometime subsequent to delivery of the solar panels.

3.6 HOT TEMPERATURE TEST APPARATUS

The contractor shall fabricate a Hot Temperature Test Apparatus that will allow a Large Area Pulsed Solar Simulator (LAPSS) to flash thirty or more flight panels as well as the Test Panel Assembly while the panels operate at the Highest Predicted Temperature as defined in the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). Please note that this temperature is higher than the Highest Predicted Operating Temperature. The Contractor shall provide means to allow electrical connection to the panels while they are at their highest predicted temperature.

The Hot Temperature Test Apparatus shall be suitable for use in a clean room environment and so shall be free from products that may outgas in the clean room. The Hot Temperature Test Apparatus shall not outgas volatile condensables onto test items, in this case the LRO qualification, test, Isc and Voc Sensor, and flight panels.

3.7 BLOCKING DIODES FOR TEST

In addition to the repair parts, the contractor shall deliver to the GSFC blocking diodes of the type and from the same production lot to be used on the flight, qualification, and test panels. GSFC will test these diodes to verify their performance at the highest predicted temperature of the diodes. The contractor shall deliver the diodes in accordance with the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

4.0 QUALITY ASSURANCE

4.1 GENERAL REQUIREMENTS

4.1.1 Quality Assurance Plan/Manual

The Contractor shall implement a Quality Management System that meets the intent of the requirements of American National Standards Institute (ANSI)/International Standards Organization (ISO)/American Society for Quality (ASQ) Q9001 (2000 version) or equivalent per ANSI/ASQ9001-2000, Model for Quality Assurance Design, Development, Production, Installation, and Servicing. GSFC shall be notified of any changes to the QA program.

4.1.2 Surveillance of the Contractor

The work activities and operations of the Contractor, subcontractors, and suppliers are subject to evaluation, review, survey, and inspection by GSFC representatives.

The Contractor shall provide the GSFC representatives with documents, records, equipment, and workings areas within their facilities that are required by the representative to perform their overview activities.

4.1.2.1 Government Source Inspection

The Government may elect to perform inspections at a supplier's plant. The following statement shall be included on all contracts and/or subcontracts: "All work on this order is subject to inspection and test by the Government at any time and place".

The Government quality representative who has been delegated NASA QA functions on this procurement shall be notified immediately upon Contractor receipt of any supplier/subcontractor orders. The Government representative shall also be notified 48 hours in advance of the time that articles or materials are ready for inspection or test.

4.1.2.2 Contractor Source Inspection

The Contractor shall ensure that its contracts and/or subcontracts impose the applicable requirements on subcontractors and other suppliers. The subcontractor and other suppliers shall in turn impose the requirements on their procurement sources.

The Contractor shall perform source inspection at the subcontractor's or supplier's facilities in accordance with the procurement documentation or when one or more have the following conditions:

In process, end item controls, or tests that are destructive in nature preventing the developer from verifying quality after delivery to the developer's facility.

It is not feasible or economical for the contractor to determine the quality of procured articles solely by inspections or tests performed at the contractor's facility.

Qualification tests are to be performed by the subcontractor or supplier.

Products are shipped directly from the source to NASA, by-passing the contractor's inspection facilities.

4.1.2.3 Notification to Contracting Officer and Contracting Officer's Technical Representative

The Contractor shall notify the COTR at least seven (7) calendar days in advance of all mandatory hardware inspections, test activities, and deliveries at either the Contractor's or a sub-Contractor's facility to allow timely participation by NASA/GSFC QA personnel.

4.1.2.4 Government Mandatory Inspection Points

The Government or its representative will perform the following mandatory inspection points (MIPs). The Government may request additional MIPs if a specific process prohibits inspection at a later time. The Government and the Contractor may mutually agree to additional MIPS.

- Inspect 100% of the flight panel solder joints
- Inspect 100% of the flight panel crimps
- Inspect 100% of the flight panel conformal coating, staking, and potting
- Rework Inspection
- Pre-Ship Inspection / Data Review

4.1.3 Configuration Management

The Contractor's CM system (available for review by GSFC on request) shall control the design and hardware/software by means of drawings, specifications, and other documents and shall ensure all applicable changes are reviewed in a systematic manner to determine the validity and impact on performance, schedule, and cost. The Contractor's CM system shall have a change classification and impact assessment process that ensures Class I changes are forwarded to the Contracting Officer's (CO) for approval prior to release/incorporation. Class I changes are defined as changes that affect form, fit, function, external interfaces, or requirements as stated within this document and the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037).

The GSFC considers other changes to be Class II, which the Contractor shall control and disposition. The Contractor shall provide all Class II changes to the COTR for review purposes every month. GSFC reserves the right to review all Class II changes for technical content to ensure the proper classification has been assigned. If the Contractor determines any flight item to be non-compliant with the quality, workmanship and performance requirements of this requirement, it shall disposition via a waiver or MRB, unless the affected item is reworked to restore compliance or is replaced with a fully compliant item. The Contractor shall submit Waivers and MRBs to the COTR for final approval.

A Contractor QA representative shall be a member of the Configuration Control Board (CCB). The QA activities shall be defined in the Configuration Management Plan and described in detail in the QA Plan. Related portions of the plans shall be cross-referenced.

4.1.4 Anomaly Reporting

The Contractor shall report hardware anomalies on a flight panel to the COTR subsequent to the fabrication of the flight panel. The Contractor shall notify the COTR within 24 hours of each anomaly.

The Contractor's processes for review, disposition and approval of anomaly reports shall be described in their quality plan/manual or provided as a supplement document. In addition, the Contractor's anomaly reporting document shall describe the members of the MRB and Failure Review Board (FRB). The MRB and FRB shall include LRO GSFC participation. These processes shall ensure that positive corrective action has been taken to preclude recurrence and that appropriate audits and tests are performed to verify the implementation of the corrective action.

The Contractor shall routinely inform the COTR of MRB and FRB meeting schedules and agendas with sufficient notice to permit LRO Project participation if desired by GSFC.

At the Contractor's facility, NASA or Government representatives may participate in MRB/FRB activities as deemed appropriate by Government management or contract.

The COTR shall have disapproval rights on MRB and FRB decisions. To assure process consistency, the Contractor shall provide the LRO Project access to their LRO anomaly-reporting database.

The Contractor shall provide, as part of the monthly report, a list of all open anomaly reports and a separate list of the anomaly reports closed during the month. For each reported anomaly or nonconformance, there shall be a report that documents the investigation and engineering analysis needed to determine the cause and corrective actions to disposition the nonconformance. Reports shall be submitted to the COTR for review and approval of the disposition.

The supplier shall establish and maintain documented procedures to ensure product that does not conform to specific requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when practical), disposition of nonconforming product, and for notification to the functions concerned.

4.2 SYSTEM SAFETY REQUIREMENTS

The Contractor shall supply detailed descriptions of the design, test, operation and inspection requirements for all flight hardware and materials, GSE, and their interfaces necessary for a valid identification, assessment, control and mitigation of documented hazards. This includes technical information concerning hazardous and safety critical equipment, systems, operations, handling and materials. For all identified hazards, the Contractor shall also document hazard controls, verifications and tracking methods.

The Contractor shall address safety requirements during the TIMs.

4.3 RELIABILITY REQUIREMENTS

The Contractor shall prepare and conduct the following set of reliability analyses.

4.3.1 Failure Modes and Effects Analysis

The Contractor shall perform a Failure Modes and Effects Analysis (FMEA) in accordance with the Procedures for Performing an FMEA (MIL-STD-1629). The FMEA shall identify failures at the functional level and address attendant consequences. This analysis shall be provided to the GSFC COTR for review.

4.3.2 Electrical, Electronic, and Electromechanical Parts Stress Analysis

The Contractor shall perform parts stress analyses on Electrical, Electronic, and Electromechanical (EEE) parts and devices as employed in the circuit designs of the Flight Item to certify conformance with the de-rating requirements of EEE parts. The analyses shall be documented, and justification shall be included for all applications that do not meet the de-rating criteria. The Contractor shall use NASA document EEE-INST-002, "Instructions for EEE Parts Selection, Screening, Qualification, and De-rating" to establish criteria. Contractor de-rating guidelines may be considered in place of EEE-INST-002 guidelines but shall be submitted for approval. This analysis shall be provided to the NASA COTR for review.

4.3.3 Worst-Case Analyses

The Contractor shall perform worst-case analyses on performance critical or functional critical components for which excessive operating variations could compromise mission performance. The Contractor shall identify the worst case analyses planned to assure the design meets critical performance and life requirements. The contractor shall verify by analysis or test or both that adequate margins in electronic circuits, optics, electromechanical devices, and other mechanical items (mechanisms). When verification by analysis is used, the analyses shall consider all parameters at worst-case limits and worst-case environmental conditions for the parameter or operation being evaluated. Similarly, when verification by testing is used, the testing shall be conducted to provide as direct a measure as possible of the critical performance or function while the element is subjected to worst-case parameter variations.

4.3.4 Reliability Prediction

In accordance with the Reliability Modeling and Prediction (MIL-HBK-217), the contractor shall predict the reliability of the LRO array to meet its end of life power requirement after fourteen months in lunar orbit for the cases of no, a single, two, three, four and five strings lost.

4.3.5 Limited-Life items

The Contractor shall identify and manage limited-life items. Limited-life items include all hardware that is subject to degradation because of limited shelf life or expected operating times or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined.

The LRO Project COTR shall approve the use of an item whose expected life is less than twice the mission design life.

4.4 GROUND SUPPORT EQUIPMENT

Mechanical GSE (MGSE) and Electrical Ground Support Equipment (EGSE) and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to mitigate potential risk to flight hardware. Parts and materials selection and reporting requirements are exempted as long as deliverable flight item contamination requirements are not compromised. However, all GSE interfaces to flight hardware shall be flight quality (i.e., connectors, base plates, etc.).

4.5 DESIGN VERIFICATION REQUIREMENTS

4.5.1 Verification Requirements

The Contractor shall implement a program to verify all requirements specified in Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037).

Verification methods shall include:

Inspection: Designated as (I) and represents inspection of the physical hardware by a customer appointed qualified inspector for compliance.

Analysis: Designated as (A) and represents documentation of performance or function through detailed analysis using all applicable tools and techniques.

Test: Designated as (T) and represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

In-process production evaluation tests, and environmental stress screening tests shall also be considered to be verification tests.

4.5.2 Analysis/Trending/Reporting of Test Data

The Contractor shall record, maintain and analyze test information during the normal test program to assess performance and flight worthiness and to aid in the identification and analysis of flight hardware failures and problems.

The Contractor shall also perform trend analyses to track measurable parameters that relate to performance stability and repeatability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing through the system integration and test (I&T) phases. These parameters will be compiled in a Trended Parameters List (TPL).

The reports will be delivered as part of the Data Delivery Package and presented at formal technical reviews as appropriate.

4.5.3 Demonstration of Failure-Free operation

Not applicable.

4.6 WORKMANSHIP STANDARDS AND PROCESSES**4.6.1 Use of Alternate Workmanship Standards**

GSFC recognizes that the Contractor may have an established workmanship program equivalent to the specific standards cited herein. In these instances, the contractor may use existing standards upon review and approval by the COTR. It must be established that the developer's workmanship program fully encompasses the specific requirements of this chapter. It is the contractor's responsibility to list all deviations from the baseline workmanship standards and to provide data supporting their position/rationale.

4.6.2 Training and Certification of Contractor Personnel

The Contractor shall train and certify personnel performing work on flight hardware requiring a prerequisite set of skills and competency. The Contractor shall allow only such trained personnel to handle flight hardware.

4.6.3 Hardware, Handling, Cleaning, and Packaging

Only qualified personnel in accordance with approved procedures that address cleaning, handling, packaging, tent enclosures, shipping containers, bagging, and purging shall perform the handling of flight hardware. The Contractor shall select packaging so that it does not contaminate hardware or otherwise degrade it during shipping or storage. The Contractor shall document these procedures to be delivered to GSFC per the Lunar Reconnaissance Orbiter Solar Array Deliverable Items List and Schedule (431-LIST-000410).

4.6.4 Electrostatic Discharge Control Requirements

The Contractor shall document and implement an ESD Control Program suitable to protect the any ESD-sensitive components in accordance with the requirements of ANSI/ESD S20.20 or NASA-STD-8739.7.

Personnel, who manufacture, inspect, test or otherwise process electronic hardware or who require unescorted access into ESD-protected areas, shall be certified as having completed and shall complete the required training appropriate to their involvement prior to handling any electronic hardware.

4.6.5 Workmanship Requirements For Printed Circuit Boards, Soldered Assemblies, Harnessing, and Fiber Optics

The following workmanship standards shall apply to printed circuit boards, soldered assemblies, and harnessing.

4.6.5.1 Requirements for Printed Wiring Boards

a) Printed Wiring Board (PWB) Design:

Space Flight PWB designs shall not include features that prevent the finished board(s) from complying with the Class 3 Requirements of the appropriate manufacturing standard (e.g., specified plating thickness, internal annular ring dimensions, etc.).

- IPC-D-275, Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
- IPC-2223, Sectional Design Standard for Flexible Printed Boards
- IPC-2221, Generic Standard on Printed Board Design (for non-critical ground support equipment only as defined in S312-P-003 paragraph 1.4)
- IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards (for non-critical ground support equipment only as defined in S312-P-003 paragraph 1.4)

b) Printed Wiring Board (PWB) Manufacture:

GSFC S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses (the use of this procurement specification is required in the procurement of “Flight” and “Critical Ground Support” boards)

- IPC-A-600, Acceptability of Printed Boards
- IPC-6011, Generic Performance Specification for Printed Boards
- IPC-6012, Qualification and Performance Specification for Rigid Printed Boards
- IPC-6013, Qualification and Performance Specification for Flexible Printed Boards

The Contractor shall provide PWB coupons to the LRO COTR, or to a GSFC-approved laboratory for evaluation. PWB coupon approval shall be obtained from COTR or a GSFC-approved laboratory prior to population of flight PWBs. GSFC will ensure that analysis is performed and a response is provided within 21 days of receipt of PWB coupons.

4.6.5.2 Workmanship Requirements

The following workmanship requirements shall apply:

- Conformal Coating and Staking: NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies;
- Hand Soldering Assemblies: NASA-STD-8739.3, Soldered Electrical Connection

Crimping, Wiring, and Harnessing: NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring.

4.7 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS REQUIREMENTS

4.7.1 General

With the exception of the solar cells, Flight Unit parts shall be selected and processed in accordance with the requirements of EEE-INST-002, "Instructions for EEE Parts Selection, Screening, Qualification, and Derating (1 May 2003)". All application notes in EEE-INST-002 shall apply.

The minimum acceptable EEE part grade available for Flight Unit use is Class 2 with 100% Particle Impact Noise Detection (PIND) screening for cavity bodied devices and a sample Destructive Physical Analysis (DPA). This assumes that the radiation hardness requirements and system reliability goals are also being met. This would include parts costs, test costs, risk of test failures and reliability differences between both classes. The Contractor shall maintain an EEE Parts Identification List and shall review proposed parts with the COTR.

The Contractor shall perform Destructive Physical Analysis in accordance with S-311-M-70.

4.7.2 Plastic Encapsulated Microcircuits

The use of Plastic Encapsulated Microcircuits (PEM) is discouraged in the Flight Panels. However, when use is necessary to achieve unique requirements that cannot be found in hermetic high reliability microcircuits, plastic encapsulated parts, must meet the requirements of NASA GSFC EEE-INST-002. All PEM(s) require COTR review and concurrence. PEM usage shall be presented at the DCR and TIMs, as applicable.

4.7.3 Radiation Hardness

The Contractor shall select all parts to meet their intended application in the earth-lunar transfer and on-orbit LRO radiation environment as defined in the Lunar Reconnaissance Orbiter Solar Array Specification (431-SPEC-000037). The radiation environment consists of two separate effects: total ionizing dose (TID) and single-event effects (SEE). The Contractor shall document the radiation hardness assessment for each part with respect to both effects and include this assessment as part of the DCR Presentation Package. Test plans and reports for parts that require radiation testing shall be submitted to the NASA/GSFC COTR for review.

4.7.4 Parts Age Control

The Contractor shall not use parts that are greater than five years old unless with COTR review and concurrence. Contractors shall present justification for such use with inspection and test requirements. In no circumstances shall the Contractor use solar cells that are greater than one year old.

4.7.5 Government Industry Data Exchange Program Alerts and Problem Advisories

Contractors shall keep sufficient selection and usage records for all flight parts and materials adequate to determine applicability of any issued Government Industry Data Exchange Program (GIDEP) alerts relevant to items used on LRO. The Contractor shall review and disposition all

GIDEP Alerts for relevancy and impact. In addition, the Contractor shall review and disposition any NASA Alerts and Advisories provided to the developer by the LRO Project. Alert applicability, impact, and corrective actions shall be documented and status provided to the LRO Project on a monthly basis.

4.7.6 Reuse of Parts and Materials

EEE parts and materials, which have been installed in an assembly, and removed for any reason, shall not be used again for flight.

4.7.7 Part Notification of Failure

The Contractor shall provide failure-reporting data to NASA/GSFC COTR within 72 hours of part failure determination.

4.8 MATERIALS, PROCESSES AND LUBRICATION REQUIREMENTS

4.8.1 Materials Selection Requirements

To qualify material for flight use, the material must have a satisfactory flight heritage relevant to LRO requirements or meet the following applicable selection criteria as defined herein for:

- Vacuum out gassing
- Stress corrosion cracking (SCC)
- Manufacturing process selection
- Fastener integrity

The Contractor shall create and maintain a Materials and Processes (M&P) Identification List and shall review proposed materials and processes with the COTR. An As-Built Materials List (ABML) shall be included as part of the end item data package.

The Contractor shall not use pure tin, zinc, or cadmium in the flight or qualification panels.

4.8.2 Stress Corrosion Cracking of Inorganic Materials

Materials used in structural applications shall be highly resistant to SCC as specified in MSFC-STD-3029. A Material Usage Agreement (MUA), see Section 1.3, and a SCC evaluation form shall be submitted, Contractor format acceptable, for each material usage that does not comply with the MSFC-STD-3029 SCC requirements.

4.8.3 Lubrication Systems

The Contractor's material list shall include lubrication usage. Lubricants shall be selected for use with materials on the basis of flight heritage and valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination concerns.

All lubricated mechanisms shall be life tested unless it can be established and documented that a valid flight heritage exists to an identical mechanism used in an identical flight application or to an identical mechanism that has been separately qualified by suitable life testing.

4.8.4 Process Selection Requirements

Materials and manufacturing process information shall be provided on the materials list.

4.8.5 Fasteners

The Contractor shall comply with the procurement and test requirements for flight hardware and critical ground support equipment fasteners contained in 541-PG-8072.1.2, "Goddard Space Flight Center Fastener Integrity Requirement: Materials Procurement Requirements."

Raw materials purchased by the contractor and its developers shall be accompanied by a Certificate of Compliance and, where applicable, the results of nondestructive, chemical and physical tests. When requested, this information shall be made available to the NASA GSFC COTR for review.

4.8.6 Dissimilar Metals

To avoid electrolytic corrosion, the contractor shall not use dissimilar metals used in direct contact unless protection against corrosion has been provided in accordance with MIL-STD-889. Variances from this policy must be submitted to the government for approval.

5.0 HANDLING, STORAGE, PACKAGING, PRESERVATION, AND DELIVERY

The Contractor shall store, preserve, mark, label, package, and pack to prevent loss of marking, deterioration, contamination, excessive condensation and moisture, or damage to a solar panel during all phases of the program. The Contractor shall store and stock items in accordance with its documented procedures, which shall be subject to quality surveillance.

Contractor shall provide an aluminum-shipping container for each twenty solar panels that protects the hardware appropriately.

The Contractor shall wrap each solar panel in a non-ESD-generating vapor barrier with redundant maximum humidity indicators whenever the panel is placed in the shipping container for shipment or storage outside a controlled environment.

The Contractor shall also place shock and humidity indicators in the container and insure that it shall be capable of prolonged shipping conditions. The container shall be equipped with filtered vents to allow for safe transport by air. The Contractor shall document what action NASA GSFC is to take if the sensors are tripped when hardware arrives at the NASA GSFC receiving area. The Contractor shall include a copy of this document with shipping documentation.

By executing the act of product shipment, the supplier certifies that the product complies with all contract requirements. Prior to shipping, quality assurance personnel shall ensure that:

- Fabrication, inspection, and test operations have been completed and accepted.
- All products are identified and marked in accordance with requirements.
- The accompanying documentation (developer's shipping and property accountable form) has been reviewed for completeness, identification, and quality approvals.
- Evidence exists that preservation and packaging are in compliance with requirements.
- Packaging and marking of products, as a minimum comply with Interstate Commerce Commission rules and regulations and are adequate to ensure safe arrival and ready identification at their destinations.
- The loading and transporting methods are in compliance with those designated in the shipping documents.
- Integrity seals are on shipping containers and externally observable shock or humidity monitors do not show excessive environmental exposure.
- In the event of unscheduled removal of a product from its container, the extent of re-inspection and retest shall be as authorized by NASA or its representative.
- Special handling instructions for receiving activities, including observation and recording requirements for shipping-environment monitors are provided where appropriate.

The Contractor's QA organization shall verify prior to shipment that the above requirements have been met and shall sign off appropriate shipping documents to provide evidence of this verification. The Contractor shall ship Freight On Board (F.O.B.) Destination. The Contractor has the responsibility for any damage incurred during shipment.

The Contractor shall coordinate transportation of the panels with the GSFC COTR prior to shipment.

Appendix A. Abbreviations and Acronyms

ABBREVIATION/ ACRONYM	DEFINITION
A	Analysis
ABML	As-Built Materials List
ANSI	American National Standards Institute
ASQ	American Society for Quality
ASTM	American Society for Testing of Materials
BOL	Beginning of Life
CCB	Configuration Control Board
CCR	Configuration Change Request
CM	Configuration Management
CMO	Configuration Management Office
CO	Contracting Officer
COTR	Contracting Officer's Technical Representative
DCR	Design Conformance Review
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic, and Electromechanical
EGSE	Electrical Ground Support Equipment
EOL	End of Life
ESD	Electrostatic-Discharge
F.O.B	Freight on Board
FMEA	Failure Modes and Effects Analysis
FRB	Failure Review Board
GIDEP	Government Industry Data Exchange Program
GSFC	Goddard Space Flight Center
HDBK	Handbook
I	Inspection
I&T	Integration and Test
IPC	Association Connecting Electronics Industries
Isc	Short-Circuit Current
ISO	International Standards Organization
JPL	Jet Propulsion Laboratory
LAPSS	Large Area Pulsed Solar Simulator
LRO	Lunar Reconnaissance Orbiter
M&P	Materials and Processes
MeV	Mega-electron Volts
MGSE	Mechanical Ground Support Equipment
MIL	Military
MIP	Mandatory Inspection Point
MRB	Material Review Board
MRR	Manufacturing Readiness Review

ABBREVIATION/ ACRONYM	DEFINITION
MSR	Monthly Status Report
MUA	Materials Usage Agreement
NASA	National Aeronautics and Space Administration
PDF	Portable Document Format
PEM	Plastic Encapsulated Microcircuits
PER	Pre-Environmental Review
PG	Procedures and Guidelines
PIND	Particle Impact Noise Detection
Pmax	Maximum Power
PSR	Pre-Ship Review
PWB	Printed Wiring Board
QA	Quality Assurance
RLEP	Robotic Lunar Exploration Program
SCC	Stress Corrosion Cracking
SEE	Single-Event Effects
SOW	Statement of Work
SPEC	Specification
STD	Standard
T	Test
Telecon	Telephone Conference
TID	Total Ionizing Dose
TIM	Technical Interchange Meeting
TPL	Trended Parameters List
TQCM	Temperature Controlled Quartz Crystal Microbalances
Vmp	Voltage at Maximum Power
Voc	Open-Circuit Voltage